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BULLETIN No. 21. V. P. P.—74.

U. S. DEPARTMENT OF AGRICULTURE.
DIVISION OF VEGETABLE PHYSIOLOGY AND PATHOLOGY.
B. T. GALLOWAY, Chief.

TWO DISEASES OF RED CEDAR, CAUSED BY POLYPORUS JUNIPERINUS N. Sp. AND POLYPORUS CARNEUS Nees.

A PRELIMINARY REPORT.

BY

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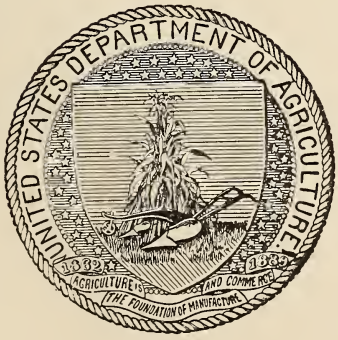

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Division of Vegetable Physiology and Pathology,
Washington, D. C., April 6, 1900.

Sir: I respectfully transmit herewith a paper on two diseases of red cedar, giving the results of investigations by Dr. Hermann von Schrenk, of the Shaw School of Botany, St. Louis, Mo., and special agent of this Division. The growing interest in forestry and forestry problems has brought about a demand for more information on the many diseases to which timber is subject. In order to obtain a better understanding of the diseases Dr. von Schrenk was engaged the 1st of July last to extend a series of investigations which had been inaugurated at the Shaw School of Botany. Through the kindness of Dr. William Trelease, director of the school named, a plan of cooperation has been effected, which it is believed will result in much benefit to the Department.

This paper is the first of a number on timber diseases that we hope to issue, and I respectfully recommend that it be published as Bulletin No. 21 of this Division.

Respectfully,

B. T. Galloway,
Chief of Division.

Hon. James Wilson,
Secretary of Agriculture.

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TWO DISEASES OF RED CEDAR, CAUSED BY POLYPORUS JUNIPERINUS N. Sp. AND POLYPORUS CARNEUS NEES.—A PRELIMINARY REPORT.

INTRODUCTION.

Of the eight or more species of Juniperus in the United States, only two, the red cedar (*Juniperus virginiana*) and Southern red cedar (*J. barbadensis*), are of general commercial importance. The former is of quite general distribution throughout the northeastern United States,[1] its habitat extending from southern Nova Scotia and New Brunswick south to Florida, and west to the Dakotas, central Nebraska, Kansas, and Oklahoma. The Southern species occurs in the South Atlantic and Gulf Coast regions, extending southward through Florida.

Red cedar has long been valued because of its beautiful, aromatic, and durable wood. It is used to a considerable extent for interior finishing of houses, for sills, in the manufacture of lead pencils, and for cabinetwork, and is admirably adapted for chests and wardrobes. The wood is very resistant to the ordinary agents of decay, and on this account is much used for fence posts, and for other purposes where wood which is durable is desirable. The trees are slow growers and do not live to be very old. They are liable to be attacked by fungi after they have reached the age of fifty to seventy-five years, and these weaken the trunk and destroy the wood.

An investigation of the nature of the diseases of forest trees must necessarily extend through many years, for, to establish the absolute connection between one of the higher fungi and the effects which its mycelium produces in a tree, it is imperative that the disease be first produced in a healthy tree. This requires a long period, owing to the slow growth of the fungi, and for this reason, therefore, the investigations from a pathological standpoint are as yet far from complete. The following data are drawn largely from observations, and, owing to the conditions under which the work was necessarily carried on, many

[1] Bull. No. 17, Division of Forestry, U. S. Dept. of Agr., and Sargent, C. S., North American Silva, 1896, Vol. X, p. 94.

of the observations are also incomplete. Owing to the large area over which the trees grow, the conditions are very varied. Moreover, the opportunities for obtaining material are restricted to localities where the timber is cut for commercial purposes, and these localities and the manner in which the trees are cut are often unfavorable to research.

The writer is under obligations to Mr. W. B. Earthman, of Murfreesboro, Tenn., and Mr. Fred Heim, of St. Louis, for courtesies which they extended to him while pursuing his studies in their localities, and also to Dr. W. G. Farlow and Prof. L. M. Underwood for their courtesy in allowing him to examine their herbaria of Polypori.

WOOD OF THE RED CEDAR.

The wood of red cedar is rather light and soft and its tensile strength is not great. The heartwood is a deep red; the sapwood is very narrow and very white, contrasting markedly with the dark heartwood; the annual rings are very narrow, owing to the slow growth of the tree (the trunk shown in Pl. III has 65 rings, of which 16 belong to the sapwood). There are no resin ducts, as in the wood of the pine, but numerous isolated resin cells are scattered throughout the annual rings, and in the heartwood these are generally filled with a hardened resin.

GENERAL REMARKS ON THE DISEASES OF THE RED CEDAR.

Comparatively few diseases of the red cedar have heretofore been described. The most important fungi attacking this tree cause the so-called cedar apples, these being due to species of Gymnosporangium. The mycelia of these fungi flourish in the wood of the youngest branches and stimulate the cambial cells, causing them to grow very rapidly and form swellings or tumors,[1] and in one case they have been known to cause a witches' broom. The influence of these fungi on their host is not marked. They deform a few branches, but unless very plentiful do but little damage.

The mycelia of two fungi grow in the heartwood of many of these trees and bring about characteristic changes which render the wood unfit for lumber. In some cases entire car loads of cedar posts shipped from Tennessee and Missouri have been found to be so badly rotted by one or the other of these forms as to be of little value. One dealer in cedar lumber estimates that at least 60 per cent of the trees in his locality are defective owing to these fungi. A careful study of the trees in the neighborhood of Murfreesboro, in central Tennessee, and also of those in southern Missouri showed that both forms of decay were present in each region. Very few insects bore into the heart-

[1] Wörnle, Paul, Anatomische Untersuchung der durch Gymnosporangium-Arten hervorgerufenen missbildungen (Forst. Naturwiss. Zeitsch., 1894, Vol. III, p. 68).

wood, the only one found in the investigations here described being a large carpenter bee, which made long tunnels through the entire length of the trunk. Here and there a few borers get in after the tree dies, as shown in Pls. V and VI.

WHITE ROT OF THE RED CEDAR (POLYPORUS JUNIPERINUS N. SP.).

Of the two forms of fungi attacking the red cedar the most striking is the one which ultimately causes long holes in the heartwood. These holes often unite and thus make a tube through the entire trunk. The trees attacked by this disease are seldom less than 25 years old and generally are much older. When a diseased tree is cut down several holes are found in the heartwood, the size of these varying according to the stage of decay. (Fig. 1 and Pl. III.) At first the holes are separated by long stretches of wood, which is apparently unchanged. A close examination, however, shows that this wood is not as deep a red as is the sound wood, but has become somewhat of a red brown. The holes themselves are coated with a brilliant white lining (Pl. II), which presents a striking contrast to the deep red of the heartwood. The layer of sound wood immediately outside the white lining has the same red brown color as the wood between the holes, and the successive rings outward from the hole show all shades of color from the red brown to the pure red of the sound wood. The holes are from 3 to 6 inches long and of variable width. They are partially filled with a velvety mass of reddish yellow mycelium, which glistens with many drops of a colorless liquid, apparently exuded by the hyphæ, and with masses of wood fibers of a reddish brown color in the last stages of disintegration. From the ends of the holes long, glistening white fibers project into the cavity, and on the longitudinal walls these fibers extend from end to end. (Pl. II.) The fibers consist of almost pure cellulose of the original wood elements, the encrusting lignin substances having been removed. In

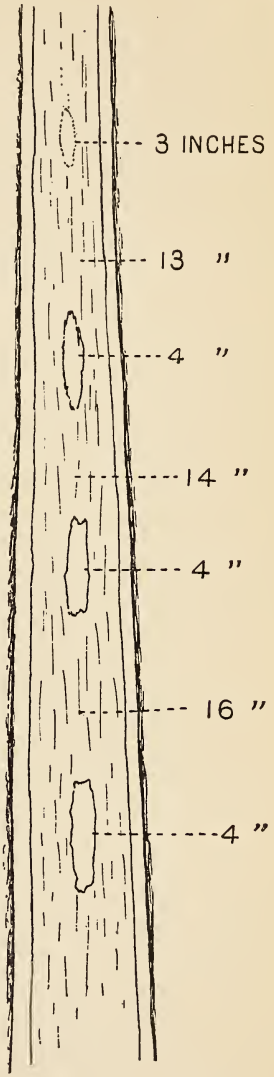


FIG. 1.—Longitudinal section of a cedar log showing position of holes caused by *Polyporus juniperinus*.

large holes the amount of wood fiber which has been reduced to cellulose is very considerable (often as much as 300 grams of this cellulose is present). The masses of cellulose consist of individual wood cells, which can be pulled out with a needle. The whole mass is very soft and can be squeezed between the fingers much like the wood pulp in a paper mill after treatment with zinc chloride. In older holes the white lining is almost absent (see largest hole, Pl. III), the walls being covered with a felt of soft brown mycelium, which often assumes very fantastic shapes. This is especially true where the proximal end of a branch projects into a hole, the wood of the trunk surrounding the branch having been destroyed and the more resinous end piece of the branch resisting the attacks of the fungus. Around this end piece the mycelium forms spherical masses of the size of a small marble. These felts are dry and elastic, and sometimes there are 20 or 30 of them together.

The holes are generally in the center of the trunk and extend longitudinally through it, one above the other, with partitions of sound wood between. (Fig. 1.) In the larger trees there are frequently several holes in the same cross section. (Pl. III.)

These holes may ultimately join here and there by the absorption of the intervening walls. They are largest at the base of the trunk, the size diminishing from the base upward, as shown in fig. 1. The distance between the holes varies from 6 inches to 3 feet.

CHANGES WHICH THE FUNGUS CAUSES IN THE WOOD.

The changes which occur in the wood after the entrance of the mycelium are of two kinds. In the first kind the original red color fades somewhat, the change being barely noticeable when the light is reflected at an angle. Very soon, however, the wood fibers in a given region turn white, showing that the lignin is being destroyed. Such a stage is shown in Pl. I. In this case the wood fibers of about eight annual rings are affected, the change being almost uniform throughout the whole mass. With the increased growth of the mycelium the wood fibers of the adjoining annual rings are attacked and are changed to cellulose. At a later stage the central mass is entirely absorbed and leaves a small hole, which gradually increases in size until it becomes 6 to 8 inches long and 2 to 3 inches wide. (Pl. II.) Around this cavity wood fibers in various stages of decomposition occur, some just beginning to change and others entirely reduced to cellulose.

In the second form of decay the red color disappears very slowly and the wood fibers gradually become brittle and finally fall apart in tangential layers. In Pl. II a wide ribbon of such wood fibers is shown extending from the left of the white area downward. The cavity is partially filled with wood fibers such as these, together with the mycelium. The cellulose fibers are never found loose in the cavity,

being invariably attached to the margins of the hole. The red of the heartwood, the white of the cellulose fibers, and the intermediate color stages, together with the red brown of some of the fibers and the yellowish tint of the mycelium, make a combination of color rarely equaled. Unfortunately much of the brilliancy of the original is lost in the photograph.

The destruction of the wood fibers laterally takes place within well-defined limits, as is well shown in Pl. II. The disintegration has taken place up to one annual ring, everything toward the middle of the trunk being changed and every part outside of this one ring remaining unchanged, which indicates that the agent which brings about the change in the wood fibers permeates one ring and changes it before attacking another.

The upper and lower ends of the hole are by no means as sharply bounded. The penetration of the destroying agent seems to take place unevenly, eating more rapidly at some points than at others. This localized disintegration shows that the ferment, for such the active agent probably is, is able to pass longitudinally along the annual rings more readily than across them.

The first form of decay.—Structural changes in the wood fibers become visible shortly after the hyphæ have entered their lumen. In this form of decay[1] the primary lamella begins to have a granular appearance and very soon after is dissolved. At the same time the color of the secondary lamella becomes lighter, and then perfectly white. With chlor-iodide of zinc these lamellæ give the characteristic blue color, indicating that they are cellulose. After the solution of the primary lamella the individual cells fall apart. The cellulose fibers are perfectly smooth and there are regular perforations on their radial walls, indicating the former position of the bordered pits. (Pl. VII, fig. 5.) This mode of delignification agrees with that described by Hartig[2] for wood of the pine delignified by mycelium of *Trametes pini*. The character of the resulting cellulose fiber is very different from that of *Pinus echinata* or *P. palustris* when delignified by *Trametes pini*. The change in the red cedar from wood substance to cellulose is very complete and takes place over large areas.

The chemical nature of wood substance is as yet a matter of much discussion. Substances called lignin compounds, coniferin, etc., to which the characteristic properties of wood were attributed, have been isolated from wood fiber. Czapek[3] has recently announced the discovery of a compound, which he calls "hadromal," that is supposed to

[1] The word decay is used to indicate changes in which substances that are not normal wood are formed.

[2] Hartig, R., Zersetzungserscheinungen des Holzes, p. 36.

[3] Czapek, Fr., Über die sogenannten Ligninreactionen des Holzes (Hoppe Seyler's Zeitschr. f. Phys. Chem., 1899, Vol. XXVII, p. 141).

give the reactions so characteristic for wood fiber—that is, red coloration with phloroglucin and hydrochloric acid, and has also obtained an enzym[1] from the mycelium of *Merulius lachrymans*, which acts on wood fiber, destroying the hadromal and leaving pure cellulose fiber. Czapek obtained this enzym by grinding the mycelium with emery powder and making an aqueous extract, precipitating the enzym with excess of alcohol. He was able to demonstrate the gradual destruction of the hadromal, beginning with the tenth day. Owing to lack of fresh material no attempt has so far been made to obtain such an enzym from cedar wood. The enzym, however, has been extracted by the writer from the mycelium of *Polyporus subacidus* growing in spruce wood. If it be assumed that such an enzym brings about the above-described changes in the cedar wood, it must necessarily be regarded as very potent.

The formation of the diastase ferment by the mycelium of wood-destroying fungi is very insignificant when compared with this lignin-splitting enzym, which in a single cavity may convert several hundred grams of wood into cellulose. It is hoped that the enzym itself will be obtained before long.

The second form of decay.—The second and less common form of disintegration begins after much of the wood has been changed to cellulose, but as to whether it has any connection with the first form it is impossible to say as yet. It is very much like the transformation of cypress wood, where it is the common form of decay, while the reduction to cellulose is the second or exceptional form. The first noticeable symptom of the second form of decay is the failure of the inner portion of the thickened ring of the bordered pits to stain as deep a red as in sound wood. Soon after this the edges of the small circle of the pit appear to be corroded and the size of the hole increases. A tangential section through the pits shows that the secondary lamella is being gradually dissolved, thus increasing the size of the cavity. The tertiary lamella and the torus are as yet unaffected. The latter is sometimes torn away by the knife and may be seen hanging out on one side. At this stage a thin, veil-like membrane, consisting of the tertiary lamella, may be seen extending into the larger circle of the pit. Pl. VII, fig. 4, shows the same in dotted lines. Finally this membrane is entirely absorbed, leaving a clear, round hole, as large as the original pit (Pl. VII, fig. 7). The torus likewise disappears, and the solution of the secondary lamella has progressed. Pl. VII, fig. 4, shows a radial view of several tracheids. A stage with the round holes is shown in Pl. VII, fig. 2, and fig. 3 represents a piece of wood at a later stage which has become detached and is lying free in one of the cavities.

The solution of the primary lamella causes adjoining tracheids to

[1]Czapek, Fr., Zur Biologie der holzbewohnenden Pilze (Ber. d. Deut. Bot. Ges., 1899, Vol. XVII, p. 166).

separate, except here and there where small portions of the undissolved primary lamella still unite them. In the illustrations (Pl. VII, fig. 3) these parts are black. When they disappear the halves become free—the stage shown in Pl. VII, fig. 4. The dotted lines in this figure represent in perspective the margins of the hole, and two large holes in the tangential wall, where some of the hyphæ had passed through, are also shown. The holes are exceedingly numerous, puncturing the cell in all directions.

In the first stages of corrosion of the pits a change in the medullary rays becomes evident. The walls are very rapidly disintegrated, and even before there is much indication of change in the tracheids the medullary rays have disappeared entirely, leaving long holes, which extend in all directions from the original center of attack (Pl. VII, fig. 1). By the time the pits of the tracheids are gone the piece of wood has turned yellowish brown and has become very brittle. The numerous holes made by the hyphæ and the absence of the medullary rays and the primary lamella readily explain why such wood crumbles into a fine powder at the slightest touch. The parts that exist longest are held together by only the infinite number of fine hyphæ which surround them. In certain portions of the wood there are holes which show no disintegration whatever into cellulose. The small hole shown at the bottom of Pl. III is one of this kind.

THE MYCELIUM.

The mycelium of the fungus is found in the wood between the holes, as well as in the sound (?) wood around the cavities. In the newly invaded portions of the trunk it is almost colorless. The hyphæ are of various sizes, and the larger ones extend longitudinally within the tracheids, giving off branches which penetrate the walls in all directions. The hyphæ never fill a tracheid completely. Within the holes the mycelium forms large sheets and webs, the latter looking very much like ground spiders' webs. When first found in the holes, the mycelium of the sheets is composed of thick-walled hyphæ of a tawny yellow color. During the later stages of decomposition the tangential plates above referred to are found completely interwoven with the hyphæ. These plates hold the ultimate pieces of the wood fibers in position, surrounding them on all sides, and finally absorb them entirely.

PROGRESS OF THE DISEASE.

The condition in which the holes are found makes it possible to describe their formation. The fungus apparently enters the trunk through a dead branch, and when the hyphæ reach the heartwood they grow both upward and downward. What factors determine the spot where disintegration of the wood begins is as yet unknown. At one point, generally a distance from the place of entrance, some

of the darkened fibers change in color and very soon have a snow-white appearance. At first this point is a mere spot, but it gradually expands and in a short time attains a length of several inches (Pl. I), the longitudinal growth being more rapid than the lateral. Around this point an area of several inches of wood is changed to cellulose, and now the total absorption of some of this cellulose begins and a small cavity starts and gradually increases in size. About this time white spots, similar to the first one, appear in the heartwood at a point from 3 to 5 feet on either side of the first hole—that is, the mycelium of the fungus has grown longitudinally and set up two new centers of destruction. A vigorous growth of the hyphæ takes place at these centers, and this growth invades the wood in all directions and brings about the characteristic changes very rapidly. In due time other centers arise farther up and down the trunk. The older holes continue to increase in size until they attain their greatest proportions, reaching the lateral limit very soon, as they are rarely more than 2 to 3 inches wide. The cavities extend up and down and frequently unite. The absorption of the cellulose goes on until none is left. The walls of the cavities then become coated with the brown felt of hyphæ before mentioned, or the second form of decay may have set in, leaving fine plates of wood hanging from the surfaces.

The setting up of these centers at which the destruction of the wood takes place is very difficult to account for, and at this time no explanation can be given of the singular mode of action. It was at first thought that the centers might be due to separate infections, but it was soon proved that this was not the case, as the hyphæ were absent from the outer layers of wood. A case which to some extent resembles the one under consideration is that of a recently described disease of Taxodium,[1] in which there is similar local action of the mycelium. The cavities in this case are very close to each other, and it seems probable that a product formed from the wood by the fungus might play an active rôle in limiting the growth of the mycelium to certain areas. Further work on this part of the subject is in progress.

THE FRUITING BODY.

After decomposition has advanced sufficiently the fruiting body forms on the outside of the trunk. This body does not appear to be common, for as far as known it has been collected only twice, once in 1895, by Miss Sadie F. Price, at Bowling Green, Ky., this specimen being now in Prof. L. M. Underwood's herbarium, and once by the writer near Murfreesboro, Tenn.[2] Nothing is known of its develop-

[1] von Schrenk, H., A disease of *Taxodium distichum* known as peckiness, etc. (Eleventh Annual Report Missouri Botanical Garden, 1899).

[2] The description here given is based on these two specimens and may have to be modified when more specimens are studied.

ment. The specimen found at Murfreesboro grew about 40 feet from the ground, and proved to be one of the Basidiomycetes belonging to the genus Polyporus. The mycelium had grown out through the wood of a dead branch, as shown in fig. 2 and Pl. IV, and had spread around this branch, forming a more or less hoof-shaped sporophore. The latter was several years old when examined, as shown by successive layers, which are plainly visible in the figure referred to. It is very hard and woody, and its upper surface is rough, irregular, and yellow brown at the margin (which is the youngest layer), soon becoming deeper brown, and finally much cracked and overgrown with mosses so that no color is distinguishable. The hymenial layer is almost horizontal, and is yellow brown in color, the yellow predominating. It extends to the very edge of the pileus and even somewhat over the edge. Each year when a new layer is added several rows of

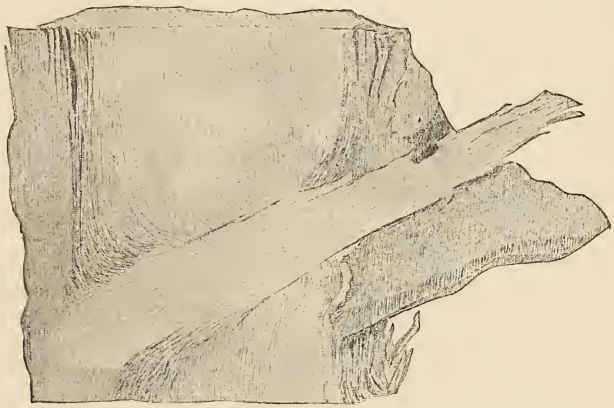


FIG. 2.—*Polyporus juniperinus* growing out from cedar trunk (x$\frac{1}{3}$).

tubes of the hymenium may be seen on the edge of the ridge, indicating where the edge of last year's pileus was. This feature is very characteristic, being well marked in both specimens mentioned, and readily distinguishes this form from *Polyporus fomentarius* and *P. igniarius*, its nearest allies. The pores of the hymenium are small and very numerous. Many of them are irregular, but the majority are quite round. The hymenium is almost smooth, for there are no hairs and the blunt cystidia project but little over the surface. The basidia are numerous, and each has four short sterigmata bearing four red-brown spores, which are more or less flat on one side. (Pl. VII, fig. 2.)

This Polyporus is one of the fomentarius type, differing from that species (a typical form of which occurs on birches in New England) in being flatter, in the character of its pores, in the color of its hymenium, and in its physiological behavior. It differs still more from *P. igniarius*, and for this reason it is proposed to call the species *Polyporus juniperinus* n. sp., to be characterized as follows: A Polyporus

of the fomentarius type, flat, hoof-shaped, very hard, upper surface at first yellow brown, then becoming fissured and black; hymenium yellow brown, with numerous small, round pores, which extend out over the edge and partially onto the top of the pileus; found on *Juniperus virginiana* in Kentucky and Tennessee.[1] A study of other specimens, only two of this Polyporus having yet been seen, may prove that these characters are not constant, in which case the form should be considered a form of *Polyporus fomentarius*.

RED ROT, OR PECKY CEDAR (*Polyporus carneus*).

General characteristics.—This disease is perhaps more common than the white rot. It has been found in Missouri, Arkansas, Kentucky, Tennessee, Virginia, and New York; has been reported from Mississippi; and has been received from Bermuda on the wood of *Juniperus bermudiana*, which shows the disease in marked form. It doubtless exists in other States in which the cedar grows in quantity. The wood of arbor vitæ (*Thuya occidentalis*) found in Maine by the writer often had the characteristic brown pockets. Wood affected with this disease is full of pockets. (Pl. V.) In the early stages these are free from one another and are more or less filled with a brown metamorphosed wood substance which has cracked so as to form small cubes adhering to the walls of the pockets. The pockets are of different sizes, varying in length from 1 inch to several feet. In cross section they are nearly circular when small, but become very irregular when old. (Pl. VI.) Frequently a number join and make large, irregular holes, full of the brown wood. The latter has the appearance and properties of brown charcoal. It is very brittle and can be ground into an impalpable powder in a mortar. When boiled in water it acquires the consistency of cheese and can be cut with ease and readily compressed into a small volume. A mass of wood thus changed has the appearance of clay suddenly dried, which has split in the center and laterally into more or less regular pieces. The line of demarcation between the brown wood and the normal heartwood is very sharp. If the brittle wood is broken away the remnants of it can be scraped off, so as to leave the surface perfectly smooth. A very slight downward pressure on one of the cubical pieces will cause it to break off entirely. The specific gravity of the material is very much less than that of the cedar wood, and it absorbs water with great ease.

CHANGES WHICH THE FUNGUS CAUSES IN THE WOOD.

The structural changes caused by the fungus in the wood are but slight, but the chemical changes are very great. When cut into sec-

[1] A fungus has been reported from the Devonshire swamp, Bermuda, which may prove to be this form on *J. bermudiana*.

tions the walls of the wood cells are found to be very much thinner. They are badly curved and twisted by the knife and have lost all stiffness and elasticity. A thin section can be pushed about with a needle as if the cells were made of pieces of flexible wire jointed at the points of union. Here and there the walls are perforated, showing where the hyphæ of the fungus passed through. The chemical behavior of the walls shows that the cellulose has been removed almost entirely. When dilute KOH is added they swell to several times their normal size and dissolve in part. Acids precipitate a brown flocculent substance from such a solution, hot nitric acid dissolves the wood completely, and the addition of excess of water produces a deep orange precipitate, all of which reactions indicate great chemical changes. The three lamellæ of the cell wall may be seen, but they have shrunk, and the pits in the tracheids show four cracks, about 45 degrees apart, apparently brought about by shrinkage due to drying. Cellulose stains do not react even after treatment with KOH. With phloroglucin and HCl the wood turns red, and with thallin yellow. In certain cells red brown masses of a substance are found which are unaffected by acids or alkalies. They turn black with osmic acid or iron salts, indicating that they are probably one of the tannins. As these cells correspond somewhat with the position of the resin cells, it is possible that the brown substance is a derivative of the resin.

Continuous extraction of finely rasped cedar wood was made with absolute alcohol for six hours, using a Soxhlet's extractor, and finely powdered charred wood was similarly treated. The resulting yellow liquid was distilled until a sirupy liquid was obtained, and from this the alcohol was allowed to evaporate slowly. The substance that remained was red brown and could be readily broken into small pieces with bright fracture. It was insoluble in water, readily soluble in alcohol, and with phloroglucin and hydrochloric acid gave a red color identical with that obtained when wood fiber is treated with these reagents. The quantities of this substance obtained from charred wood and from normal wood were about equal. It was believed that the substance obtained was probably the bearer of the properties which had heretofore been vaguely regarded as lignin substance, but it proved to be identical with Czapek's hadromal.[1] Czapek obtained the same by boiling with zinc chloride and extracting the wood fiber thus treated with benzol. In the experiments here discussed the alcohol extraction proved sufficient.

It is evident that if the hadromal be the substance which gives the wood character to cellulose fiber, all fungi attacking wood do not destroy this compound, for in the brown disease of the cedar the hadromal is as abundant as in the normal wood. The same may be

[1] Czapek, l. c.

said of the charred wood of *Libocedrus decurrens*,[1] recently described. So little is known of the chemical nature of the wood fiber that it would be hazardous to attempt any discussion as to the rôle of any of the compounds found in decomposition processes. Charred wood, such as above referred to, is composed of a very small quantity of hadromal and a large part of some substance that is not cellulose, but possibly a derivative of it.

In view of the fact that for some wood the changes induced by fungi have been found to be due to enzyms secreted by their mycelia, it seems probable that the change in the wood of the cedar is brought about by an enzym. This enzym is probably distinct from any yet found, because of the very different products found as a result of its action. Many attempts have been made to secure it, but so far these have failed because of the very small quantity of mycelium which it was possible to get.

An aqueous extract of the charred wood when treated with an excess of alcohol gives a gray flocculent precipitate, which is soluble in water. Wood fibers have been immersed in such a solution, but they did not, even after standing several months, show any change.

As in the case of white rot, little is known of the life history of the fungus causing red rot. The changes which it induces have been studied in many trees, and were as follows: The first symptom noted in the heartwood was a slight change from red to brown over a considerable area. As the brown deepened, fissures began to appear and soon became very numerous. The wood shrank until pockets, such as above described, were formed. These pockets are most common near the base of the trees, where they become very large. They occur one above another, and often two unite. After a certain period no further increase in the number of pockets takes place, and the cessation of growth, as shown by this fact, is one of the problems which remains for solution, as does also the question why all growth of the mycelium should cease in the heartwood of a tree after it dies or is cut down. It seems to be a fact that many dead cedar trees are found which are partially decayed, and apparently have been in such a condition for many years. In southwestern Missouri, where the cedar grows on the rocky hillsides, many trees die after they have reached a certain age, apparently because of lack of food and water supply. Many of these trees are full of brown pockets, especially near the base.

THE MYCELIUM.

The mycelium of this fungus is very scanty, being found in quantity only here and there. The younger hyphæ are pale and have numerous clamps. They extend horizontally through the tracheids

[1] von Schrenk, H., A disease of *Taxodium distichum* known as peckiness; also a similar one of *Libocedrus decurrens*.

and give off lateral branches. No mycelium is found in the sapwood. The wood between the pockets has many hyphæ, which pass from one pocket to another.

The brown humous compound found in Taxodium[1] is entirely absent in the tracheids of this intermediate wood. In Taxodium this substance was supposed to be active in restricting the growth of the mycelium to certain areas, protecting, as it were, the wood in which it was contained. As a result holes were formed which rarely joined. In the cedar the holes join as a rule, forming very large, irregular cavities, and this would seem to bear out what has been claimed for Taxodium. There being no restraining factor, the enzym of the fungus acted in the surrounding wood, making the cavities larger and larger. There is practically no limit to the carbonization of the wood (Pl. VI), for very old trees may be almost hollow at the base, and it is no uncommon thing for such trees to be blown over when the hollow becomes so great that the sapwood is not strong enough to keep them standing.

FIG. 3.—Trunk of a red cedar showing hole under an old branch.

THE FRUITING BODY.

The fruiting body of the fungus, which was long sought for, forms in the holes so common on the trunk of the cedar and which are brought about by the manner in which the dead branches seem to recede into the trunk (fig. 3). The cedar belongs to that class of trees in which the base of a dead branch does not grow

[1] von Schrenk, l. c., p. 14.

after the branch has fallen away. In many trees, such as spruce, fir, and some pines, several inches of the base of a branch remain alive and are supplied with nutriment by the parent branch. These keep pace with the increase in the diameter of the trunk until they are healed over. In other trees the pressure of the callus causes the branches to break off, and the wound is soon healed. A dead cedar branch remains visible on the outside for many years. The addition of annual layers of wood on both sides of a branch is such that after some years the stump lies in a hole which has a lens-shaped opening toward the outside, and it is in these holes that the fruiting body of the fungus is found.

The sporophores are often small and are difficult to remove, the shredded bark hiding them. The form of the hole determines the shape of the pileus, the latter being sessile, wedge-shaped, and from ¼ to 1½ inches long and about ½ an inch in width (Pl. VII, fig. 8). If there is sufficient room in the hole the upper part of the pileus is arched forward, so as to form a distinct bracket. The hymenium is flesh-colored and has numerous very minute spores. Sometimes the fruiting organs form in the holes within the tree when the holes become exposed to the air. They are then very irregular in shape, adjusting themselves to the form of the hole. In Pl. VII, fig. 9, one of the largest found is shown, as are also a number of smaller ones. In two cases the fungus was found fruiting in holes in logs which had been cut and piled.

The mature spores have not been found, and therefore the systematic position of this form is somewhat in doubt. On account of its flesh-colored hymenium it is regarded as a form of *Polyporus carneus* Nees—a form found on dead cedar wood, as well as on spruce and fir, in which cases, however, it never brings about the brown rot. Its deformed nature is undoubtedly due to its method of growth, which is not of sufficient value as a distinct specific character, and it is therefore proposed to consider this fungus as a form of *Polyporus carneus*.

GENERAL CONSIDERATIONS.

The fungi causing the two diseases described may be considered wound parasites, which grow in the heartwood of the living trees and thus render the wood unfit for commercial purposes. Frequently the diseased trees are cut and sold for use as an inferior grade of fence posts, although they apparently last almost as long as the sound posts. The natural supply of red cedar still available is very small, hence any remedies which might be suggested in connection with the two diseases must be applicable to trees growing under modern methods of forestry for lumber or for ornament. After a tree has once become affected with either disease, remedies will not avail.

As infection occurs through the entrance of the spores into exposed places in the heartwood of a tree, where they germinate and bring about the changes described, the treatment should be preventive, not curative. All sporophores which form on the trees should be destroyed and diseased trees should be removed, as they may give rise to sporophores which may escape notice. The retention of such diseased trees as seed bearers does not seem desirable in the case of the red cedar, as there are so many healthy trees which could serve the same purpose. It is also advisable to cut trees after they have reached a certain age, as old trees are more liable to attack than younger ones, the liability increasing with age. The best age for cutting varies with locality. In very favorable situations, where the trees grow very rapidly, they may be cut with profit when but half the age at which it would be best to cut trees growing on mountains or in exposed situations, where growth is very slow. A good age at which to cut the trees in Tennessee is from 65 to 70 years—in other words, when the trunk is about 1 foot in diameter.

EXPLANATION OF PLATES.

Plate I.—A slab of red cedar, showing the first stage of decay induced by *Polyporus juniperinus*. The white spot shows the cellulose fibers (x $\frac{3}{4}$).

Plate II.—A piece of the trunk of red cedar split open to show large hole caused by *Polyporus juniperinus*. The white masses are cellulose fibers, the flocculent gray masses in the hole are disintegrated wood fibers, while above and below the ends of branches are seen (x $\frac{1}{2}$).

Plate III.—Cross section of a red cedar trunk, showing five holes caused by *Polyporus juniperinus*. Two of these are early stages and show the white lining of cellulose fibers. The cracks in the block were made when the trunk was split (x $\frac{1}{2}$).

Plate IV.—*Polyporus juniperinus* growing on *Juniperus virginiana*, showing how the pileus forms around a dead branch (x $\frac{1}{2}$).

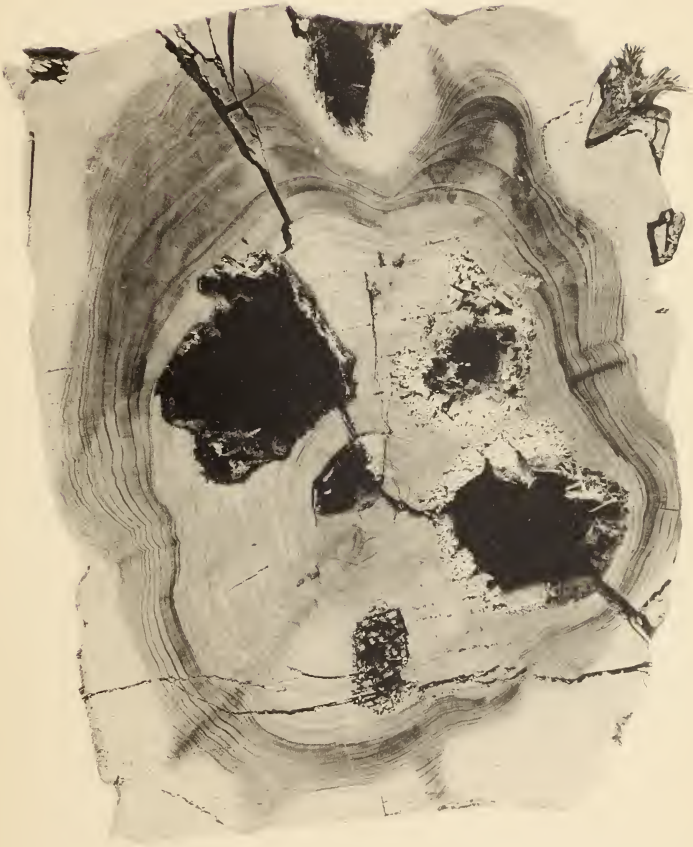
Plate V.—Upper figure, radial view of a block of red cedar, shows the early stages of decay (pecky cedar) due to *Polyporus carneus;* lower figure shows end view of several pockets uniting to form a larger area. The change from sound wood to brown wood is very abrupt.

Plate VI.—A cedar log showing large pocket, filled with brown wood, formed by *Polyporus carneus* (x $\frac{1}{2}$).

Plate VII.—*Fig. 1*, tangential view of wood from a large cavity caused by *Polyporus juniperinus*, showing how the medullary rays are first absorbed. The small holes in the cell walls show where hyphæ have bored through (x —). *Fig. 2*, tangential view of walls from same wood at a later stage. The torus is shown at *t*. The primary lamella and part of the secondary lamellæ have been dissolved. In two bordered pits the torus is still in position. *Fig. 3*, another wall, taken from spring wood, the stage of decomposition being the same as in fig. 2. *Fig. 4*, radial view of several tracheids from the same wood as shown in fig. 3: *a*, bordered pits, showing the initial stage of decay, the central opening widening; *b*, *c*, and *d*, tracheids in various stages of dissolution. The dotted lines indicate the margins of thin membranes of the tertiary lamella. *Fig. 5*, a single wood cell as it appears when changed to cellulose, from a cavity such as shown in Pl. II. *Fig. 6*, a stage in wood destruction later than that shown in figs. 2 and 3 of this plate. The dotted lines indicate the deeper margins of the holes. *Fig. 7*, a piece of badly decomposed wood lying free in a large cavity (Pl. II), the bordered pits having been entirely destroyed. *Fig. 8*, sporophore of *Polyporus carneus* Nees: *a*, lateral view; *b*, top view. The triangular shape shows how it has adapted itself to the shape of the hole in the cedar trunk. *Figs. 9* and *10*, sporophores growing in holes within the trunk. *Fig. 11*, spores of *Polyporus juniperinus* n. sp.

A RED CEDAR SLAB SHOWING THE FIRST STAGE OF POLYPORUS JUNIPERINUS.

A PIECE OF THE TRUNK OF A RED CEDAR, SPLIT OPEN TO SHOW LARGE HOLE CAUSED BY POLYPORUS JUNIPERINUS.

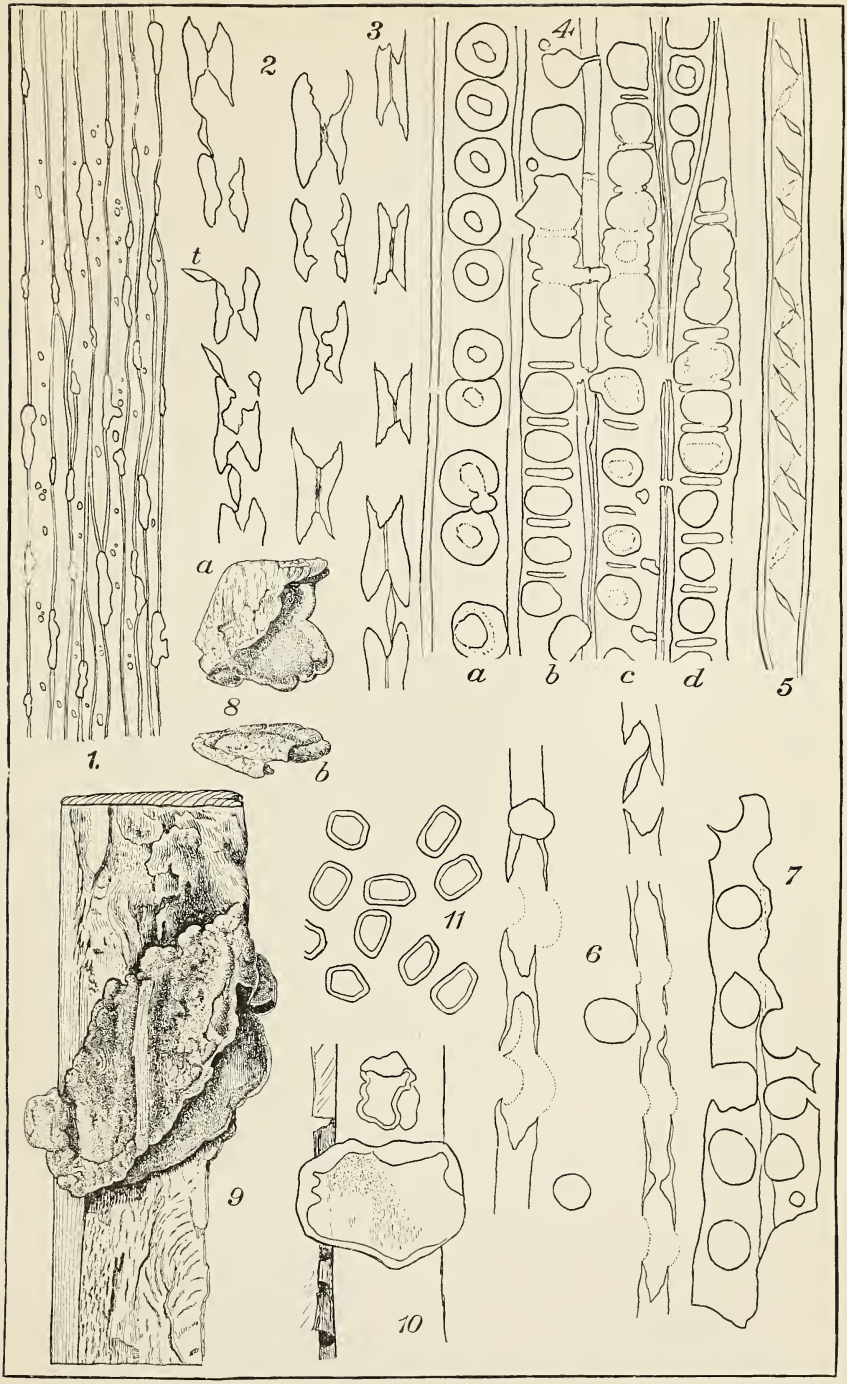


CROSS SECTION OF A RED CEDAR TRUNK SHOWING HOLES CAUSED BY POLYPORUS JUNIPERINUS.

POLYPORUS JUNIPERINUS. V. SCHRENK ON JUNIPERUS VIRGINIANA.

UPPER FIGURE SHOWS RADIAL VIEW OF BLOCK OF CEDAR IN EARLY STAGES OF DECAY; LOWER FIGURE SHOWS END VIEW OF SEVERAL POCKETS UNITING

CEDAR LOG SHOWING LARGE POCKET, FILLED WITH BROWN WOOD, FORMED BY POLYPORUS CARNEUS.



DIFFERENT STAGES OF DESTRUCTION OF CEDAR WOOD.